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The Higgs Boson Search in the Multijet Final States At CDF II, Fermilab

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- Introduction and Motivation
- The Multijet channel
- Proposed Trigger
- Kinematic studies
- Conclusions

Introduction and Motivations

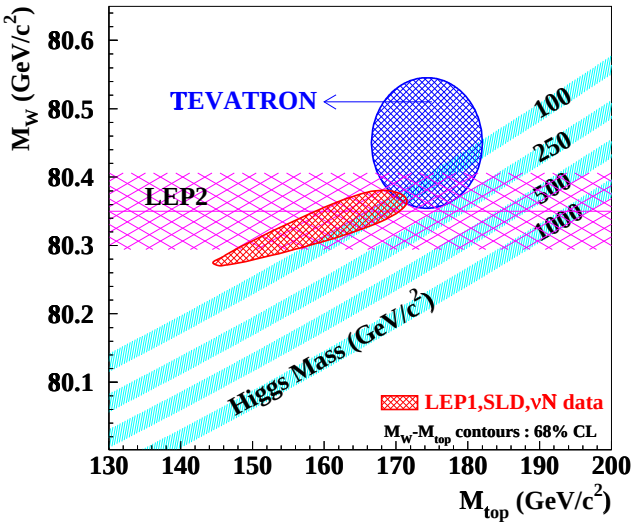
What is the mechanism responsible for the spontaneous breaking of the $SU(2) \times U(1)$ symmetry ?

Answering this question is *one of the primary goals of present and future colliders.*

The simplest model for the breaking of the electroweak symmetry requires the existence of the Higgs boson.

LEP II was unable to detect this particle so it determined an experimental lower limits on its mass:
$M_H \geq 113.2 GeV$. (95 % C.L.)

LHC will be able to discover the Higgs if $M_H > 130\ GeV$, but will be *strongly hindered by SM backgrounds* if the mass is lower.

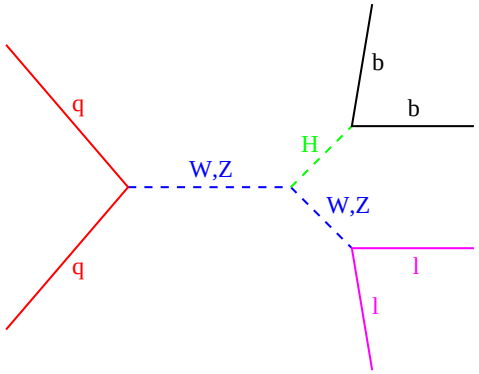


Indirect electroweak fits and direct measurements of M_W and M_{top} suggest that the Higgs boson might be light.

Higgs Phenomenology

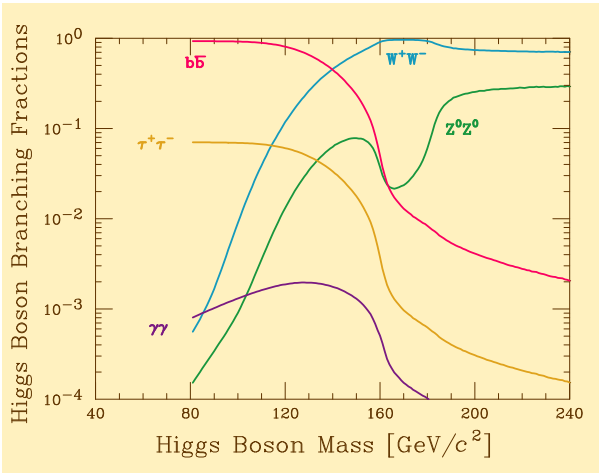
At Tevatron the two main processes by which the Higgs could be produced are:

- direct production interesting for $M_H \geq 130 GeV$ with the Higgs decay mode in a pair a W. For M_H lower strongly affected by background.
- associated production with vector bosons:



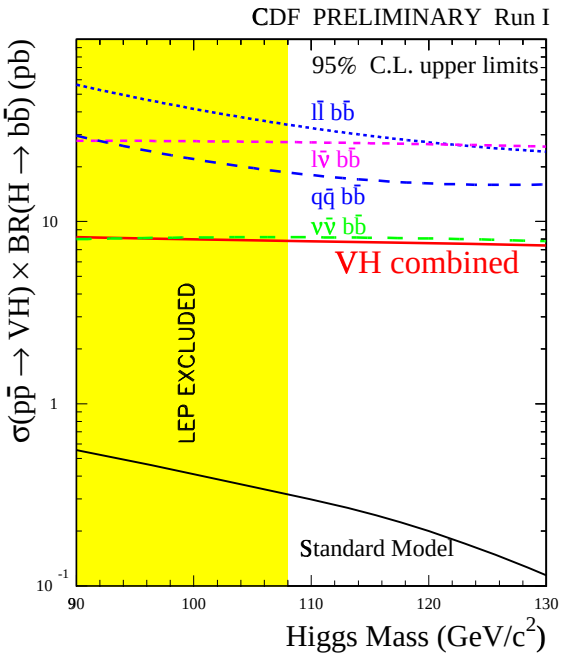
For $M_H \leq 130\ GeV$ we are interested in all final states including $H \to b\bar{b}$ decay:

- $llb\bar{b}$
- $l\nu b\bar{b}$
- $\nu\nu b\bar{b}$
- $jjb\bar{b}$



Past Higgs Searches

This plot summarizes the result of the searches for the Higgs boson in the associated production mode at CDF with Run I data.



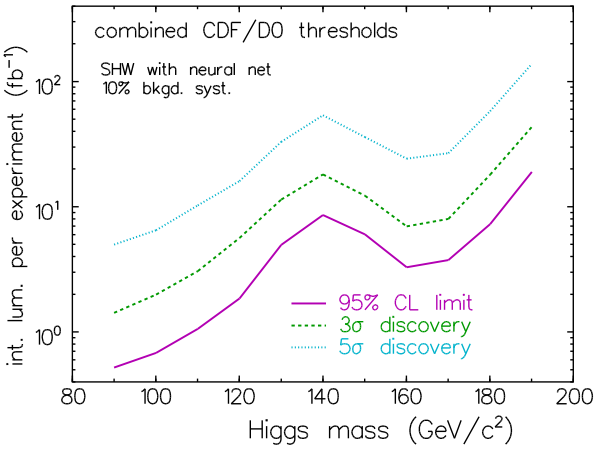
The hadronic channel showed itself competitive with the leptonic ones The Run I limit in the production cross section was set to $\sim 8\ pb$ using all the $106 pb^{-1}$ of collected data.

But in Run I the multijet trigger did not suit so much the possibility of an Higgs discovery. The trigger was designed to collect $t\bar{t} \to 6j$ events ($Efficiency_{VH \to 4j} \leq 30\%$).

Chances for a Discovery

A detailed analysis of all the possible tools for a Higgs discovery, at Tevatron, has recently been carried out by Fermilab working group (hep-ph/0010338)

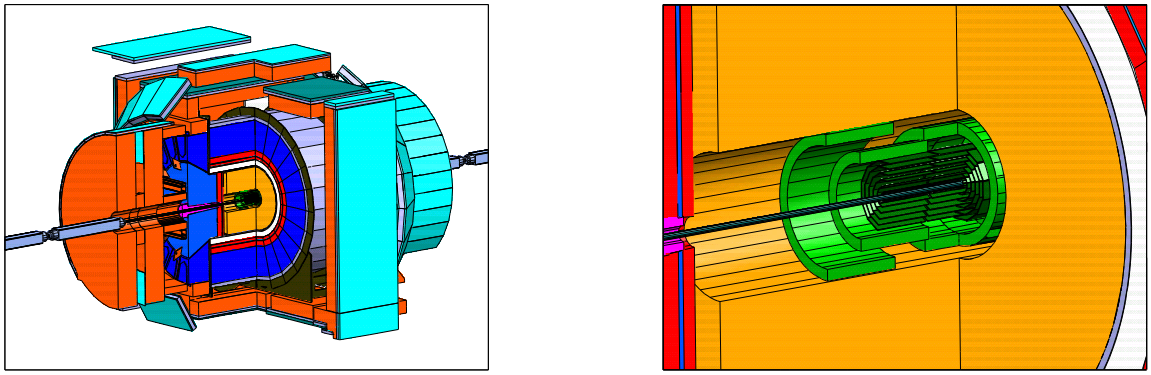
The results show that the Tevatron has encouraging chances of discovering the H boson over a wide mass range, if a luminosity of 20-30 fb^{-1}/exp. is collected. To achieve that, combining the data and considering every possible signature may be necessary.



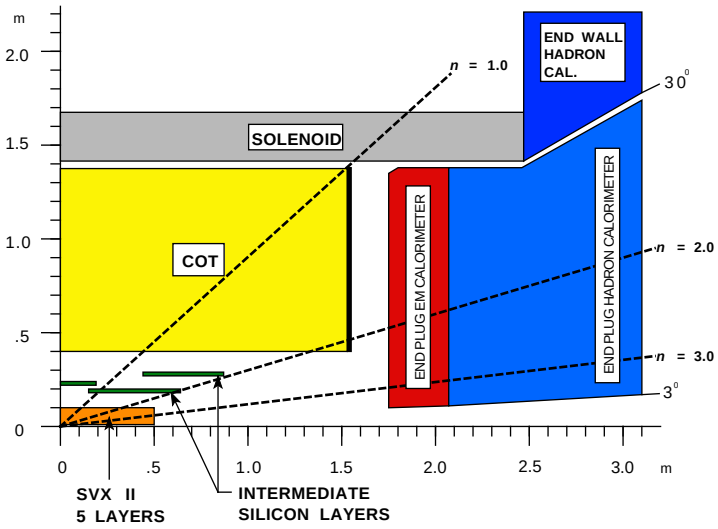
Looking forward the Higgs search in the multijet final states in Run II, it is critical to consider the possibility to have a trigger specifically designed to this aim. What we need is to have high efficiency on the signal but a reasonable rate of data collection.

CDF II detector

A multi-purpose detector designed to measure $e, \mu, \not\!\!E_T$ and jets. Inside a large drift chamber is a 7-layers silicon detector crucial to detect secondary vertices from heavy flavour decay.



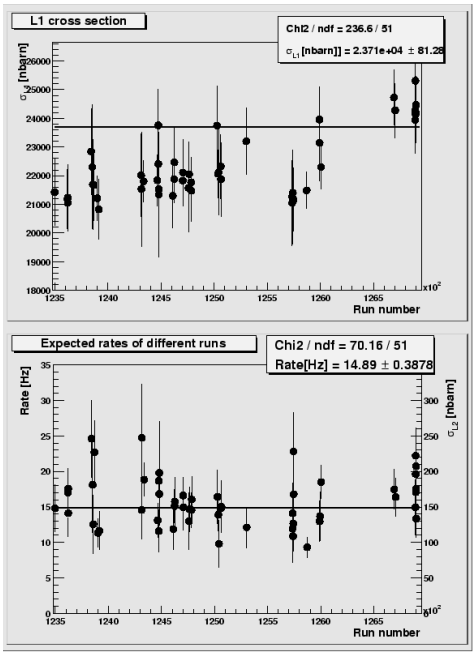
From left to right: the full detector view and a zoomed view of the inner tracking system



Multijet + SVT trigger

- Calorimetric Studies: The calorimetric requirements are divided by trigger levels
  - Level 1 threshold on single calorimetric tower.
  - Level 2 multiple calorimetric deposits requirement and global E_T threshold.
  - Level 3 multiple reconstructed jets requirement and global E_T threshold.

The L2 calorimetric rate extrapolated to the project luminosity, $10^{32}\ cm^{-2}\ s^{-1}$, (soon available) is about 15 Hz. Data results in agreement with our precedent Monte Carlo studies: we had an efficiency of about $40 \div 50\%$.



Such a rate is close to the limit of Level 3 rate acceptance. So we need a method to lower it.

SVT requirements

see the SIF-talk L'inizio del Run2 a CDF by S.Donati on $Sept.26^{th}$, 2001

SVT, the Silicon Vertex Tracker

$\Downarrow$

read the hits on the 7 silicon layers detectors close to beam line

$\Downarrow$

As output gives a set of P_T and $I.P.$ of fitted tracks

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time is enough for a Level 2 decision

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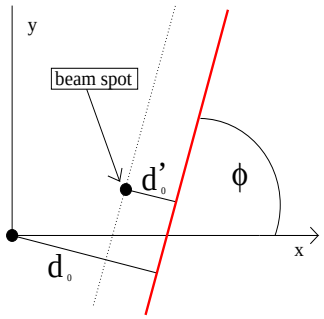
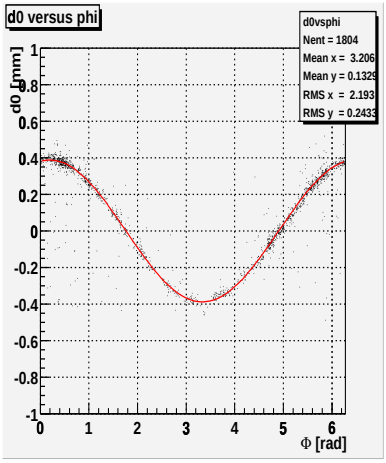
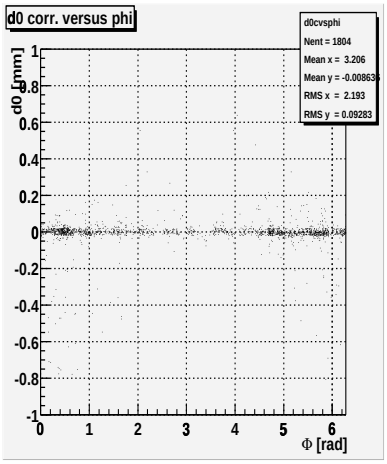
we use it to reduce our Level 2 rate



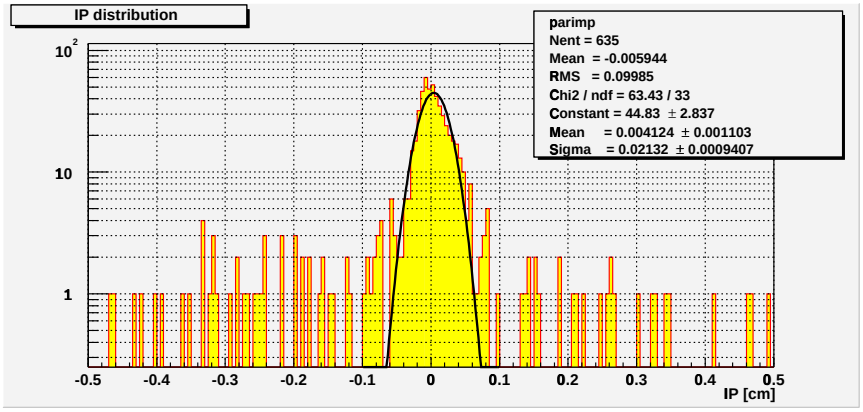




Using the new data available and considering that the beam is not in its nominal position, we fit the correlation between d_0 and ϕ, to make the necessary correction on d_0.

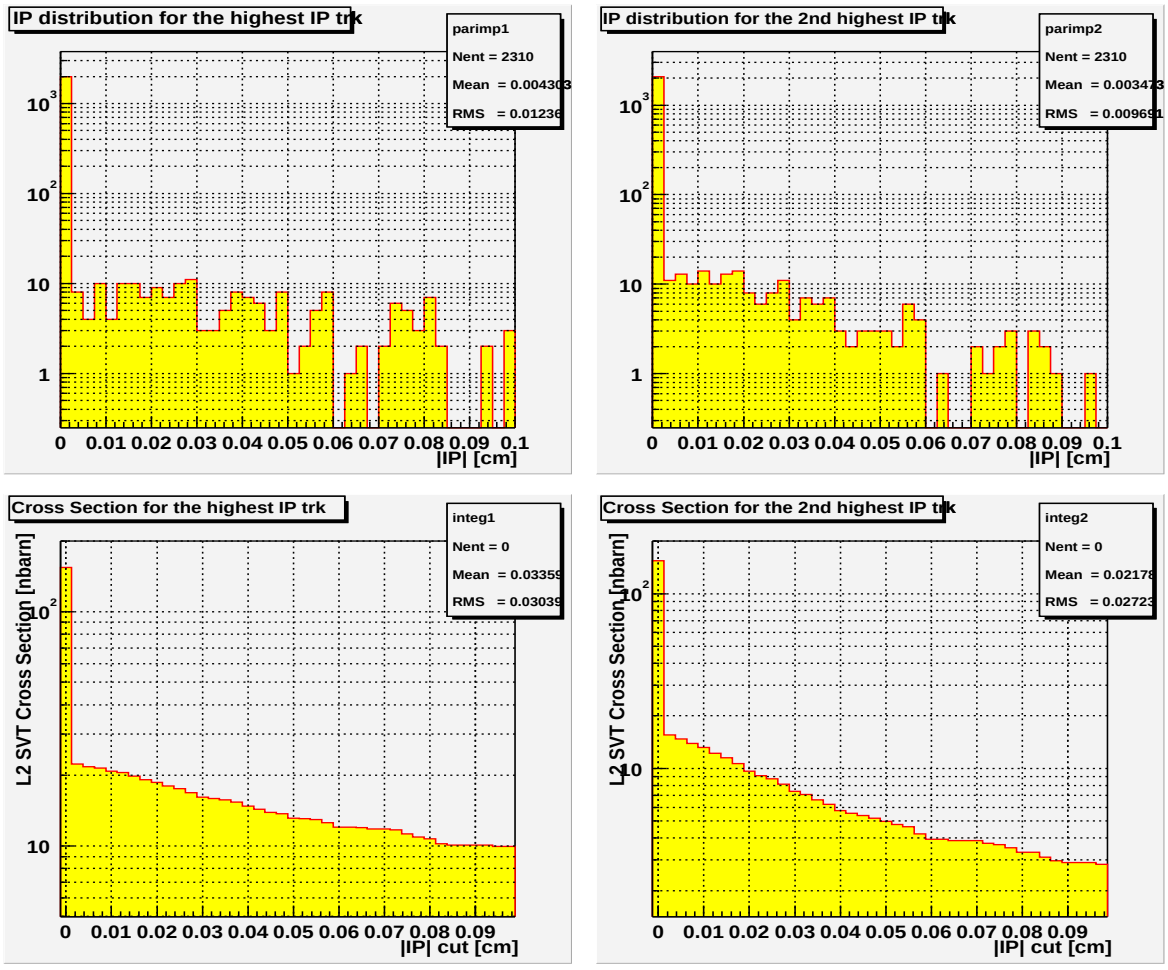
We obtain

$$d_{corr} = d_{SVT} + (x_0 + x_s * B)\sin\phi - (y_0 + y_s * B)\cos\phi.$$



The correction is not very accurate, results are only demonstrative yet.

The requirement of two tracks with $P_T \geq 2\ GeV$ and $IP \geq 100\mu m$ reduces rates by an order of magnitude, roughly as expected ($\sigma_{L2} = 15\ nb$, previous MC studies).



However, we need more data and a more accurate correction to get realistic estimates.

Kinematics

To detect the VH production signal it is necessary to discriminate it, from the QCD background as well as from other competitive processes like $t\bar{t}$, di-boson and single top production.

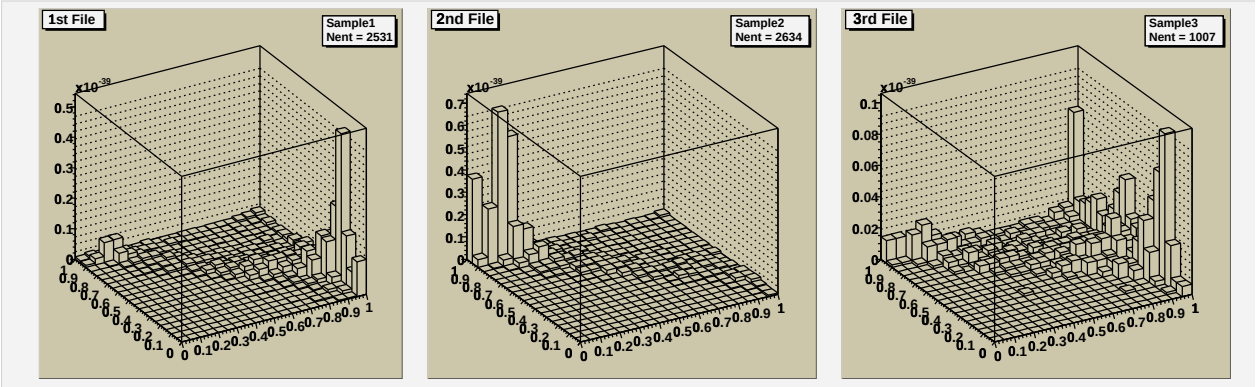
- VH events: $\sigma \cdot BR_{had} \cdot \epsilon = 0.019\ pb$
- VV events: $\sigma \cdot BR_{had} \cdot \epsilon = 0.114\ pb$
- Single Top events: $\sigma \cdot BR_{had} \cdot \epsilon = 0.095\ pb$
- $t\bar{t}$ events: $\sigma \cdot BR_{had} \cdot \epsilon = 0.97\ pb$

The QCD background yields about 1 nb.

Our plans are to search some kinematic variables able to discriminate between these processes. We use a Neural Network to do that. The variables chosen are

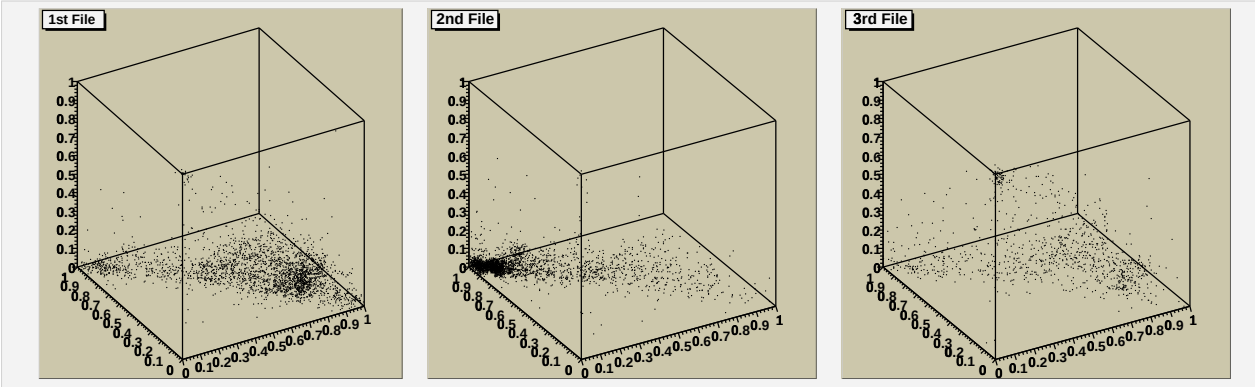
- Number of jets in the event
- $\sum E_T$, $\sum E_T^3$
- Sphericity, Aplanarity, Centrality $(= \frac{\sum E_T}{\sqrt{\hat{s}}})$
- mass of the $b\bar{b}$ -pair, of the $q\bar{q}$ -pair, reconstructed top mass

Some examples of discrimination results, using 2 outputs for the NN, are show below.



From left to right: NN2 output for WH, $t\bar{t}$, and Single top samples.

For 3 output:



From left to right: NN3 output for WH, $t\bar{t}$, and Single top samples.

Conclusions

The Higgs discovery is one of the primary goals of CDF-II. Even if the all hadronic final state should not be the best channel in which search something, it is in anyway important because an eventually discovery of the Higgs boson will be possible in Run-II only keeping togheter the forces of both CDF and D0, summing all of possible channels.

Work is ongoing to verify the feasibility of the multijet+SVT trigger. We hope this will materialize in a concrete stream as soon as possible, in order to start a collection of good data for our aim.